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CHANCE CONSTRAINED PROGRAMMING AND OTHER APPROACHES TO RISK IN STRATEGIC MANAGEMENT

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Abstract

E. H. Bowman's empirical finding that negative relations exist between risk and return for firms in a wide range of industries has stimulated work on the previously under-researched area of risk-return relations in the strategic management literature. In place of the simple mean-variance relations which have generally characterized this work, the present paper introduces more general chance-constrained programming formulations which can be used in actual management planning where, in general, multiple risks and/or returns will need to be addressed. The proposed models are preceded by a survey of existing literatures on risk-return relations. Results in different literatures dealing with these topics are interpreted and related via the concepts in this paper by means of explicitly formulated definitions of risk, strategic planning, etc., which can be used for guidance (a) when the proposed models are to be used in management planning or (b) when they are to be contracted to simpler forms for continuation of the preceding risk-return research. It is expected that this will provide openings for effecting interactions between research and practice.

Key Words:

Strategic Planning
Risk
Multiple Risks and Objectives
Chance Constrained Programming

I. Introduction

Plans are said to be *strategic* when they are to be used "to guide or control other plans." See the definition of strategy on p.489 in Cooper and Ijiri (1983). For instance, a "strategic marketing plan" may be formulated to guide the development of "marketing plans" for each of several product lines. Such a plan may, however, have to be formulated in a way that conforms the proposed activities in marketing to plans for other company activities in manufacturing and finance. Coordination and conformance between all such activities may then be accomplished by an overall company plan or corporate strategy.

Much of the literature dealing with strategic management focuses only on the latter in terms of an overall corporate strategy which sets directions or objectives intended to relate corporate developments to future environments in which the company will (or should) operate.[1] Keller (1983) is particularly strong in asserting that the focus of strategic planning should be on the latter and this should be done from the standpoint of top management involvement without cluttering detail. In treatments like the one we are undertaking, however, it is necessary to allow for variations encountered in practice as well as in the literature. Two recent examples from practice can help to illustrate some of the possible variations as follows: One example, as issued with the president's approval, is entitled *The University of Texas at Austin Strategic Plan, 1990 - 1995*, and consists of a looseleaf arrangement containing 67 double spaced typed pages of text with supporting timetables for program changes and accompanying estimates of costs plus more than 100 pages of supporting statistics and projections. The other example entitled *A Blue Print for Tomorrow's Texas* as issued by The Strategic Economic Policy Commission consists of 10 pages in a small printed pamphlet designed to provide "An Overview of the Preliminary Strategic Plan" for diversifying and developing the Texas Economy. The latter is to be distributed for discussion with interested groups such as legislative committees and local

[1] See p.489 in Cooper and Ijiri, 1983.

chambers of commerce which are concerned with planning future actions. The former has been distributed to department chairmen in the university who are being asked to develop departmental strategies for consideration by their deans and others who were involved in formulating the university's plan. Both the state and the university's plan are therefore being used "to guide or control other plans" in accord with our definition.

This paper is intended to be flexible enough to allow for the development of plans like the above in whatever detail may be desired. Models will therefore be provided which can be contracted to simple "statements of objectives" or expanded in the detail needed to ascertain (a) whether subsidiary plans with their proposed actions and accompanying resource requirements conform to overall company plans and also (b) whether all of these plans are coordinated relative to each other as well as overall corporate objectives. Our models can be also used to provide flexible responses and accompanying mechanisms for effecting evaluations when subsidiary plans suggest that further development and perhaps alteration in company objectives may be desirable.

Generally speaking, both the literature and the practice of strategic corporate planning have had trouble in dealing with the risks and uncertainties that accompany almost all future oriented activities. This topic forms a central portion of the treatments that will be covered in this paper in the following manner. First, a survey will be undertaken of the literature that has dealt with conceptualization and measurement (or evaluation) of risks for use in strategic management. En route to suggesting improved alternatives for representing and evaluating the multiple risks that may need to be considered for use in strategic management a variety of other literatures will also be surveyed such as, e.g., the finance literature. In this review of previous literature, emphasis will be on empirical studies. After this coverage of different studies has been completed an attempt will then be made to comprehend these and other developments in a more general formulation which utilizes "Chance Constrained Programming."[2] This use of chance rather than deterministic constraints will make it possible to allow for risks and/or uncertainties in an explicit manner. It will also make it possible to relate the results

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[2] See Charnes and Cooper (1959).

from the literature on risk in strategic planning literature to still other approaches such as (a) the "satisficing" approach of H. A. Simon (1957) as found in the literatures of cognitive psychology and organization theory and (b) the market-portfolio planning approaches that have been developed from the original work of H. M. Markowitz (1959).

A formal definition of risk will be proposed after the literature survey has been completed. Using this definition our chance constrained programming formulations will generally try to separately identify risks and rewards and thus provide an alternative to other commonly used approaches -- such as those found in the decision theory literature (built around variants of the von Neumann and Morgenstern utility theory formulations) in which risks and rewards are interwined in "lottery-like" formulations.[3] By contrast, the approach to be followed here will generally separate risks from rewards by assigning the former to the constraints and the latter to the objectives that are to be pursued. The guiding notion is that the constraints form conditions to be satisfied when these objectives are sought, but it is improvement in the objective which determines the manner in which the constraints will be satisfied.

Proceeding in this manner makes it possible to examine ways in which risks may be represented and evaluated relative to objectives while still retaining their separate identities. Different risks such as risks in marketing and risks associated with financing activities can be accommodated in different chance constraints so that the resulting chance constrained models readily comprehend multiple risks of different kinds. Different objectives can also be used as will be illustrated here by examples like "maximizing expected profit" (from the E-model of chance constrained programming) or "minimizing variance of profit" (from the V-model of chance constrained programming) or "satisficing" by maxi-

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[3] See, e.g., MacCrimmon and Wehrung (1986) for a use of this approach in an empirical survey of executive responses to combined risk-reward problem formulations.

mizing the probability of attaining a satisfactory level of profit (from the P-model of chance constrained programming).[4]

Of course, "expected profit," "minimum variance," and even their combinations as in "satisficing," are not the only possible objectives that might be used in actual practice. These objectives are selected here because of their common appearance in the literature. Our approach will be sufficiently general (or abstract) so that other objectives may also be used in their place. Finally, although it will not be treated here, extensions to accommodate strategy-structure interactions like those posited by Chandler (1962) can also be effected by introducing elements which allow for using different risks in the kind of joint goal selecting features which are familiar from the work of Ruefli (1968, 1971).

II. A Survey of Risk-Return Studies

1. Studies Using Mean-Return and Variance

Risk considerations received little attention in the literature of strategic management until Bowman's (1980) seemingly paradoxical findings focused attention on this topic. Using ROE (return on equity) as a measure of return and variance of ROE as a risk measure, Bowman (1980) constructed a collection of two-by-two contingency tables in which return and risk were divided into "high" and "low" classes, respectively. Using the median value of ROE and the median value of variance of ROE as the dividing points for these "high" and "low" return and risk categories, Bowman classified the firms in each of 85 industries as follows.

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[4] This development is adapted from the more general one to be found in Charnes and Cooper (1963).

	ROE Variance (Risk) High	ROE Variance (Risk) Low
ROE (average) High	High Risk-High Return	Low Risk-High Return
ROE (average) Low	High Risk-Low Return	Low Risk-Low Return

The division into "high" and "low" was effected for each firm by Bowman according to whether its average ROE for the period studied was above or below the median of the averages for all firms in the industry and the same division was used for the variance of these ROE values. That is, the median of these average values was used as the basis for assignment to the "high" and "low" classifications in both cases.

Bowman then used the following formula

$$(1) \quad \text{Association Ratio (AR)} = \frac{[\text{HL (high risk-low return)} + \text{LH (low risk-high return)}]}{[\text{HH (high risk-high return)} + \text{LL (low risk-low return)}]}$$

with AR > 1 indicating a "negative" and AR < 1 indicating a "positive" association between risk and return. In 56 of the 85 industries studied, Bowman found the association to be negative, in general, with only 21 industries where the association was found to be positive. In the remaining 8 industries the AR value was equal to unity. Applying a binomial test of statistical significance to these results, Bowman concluded that a significant negative risk-return relationship obtained for firms in the years covered by his study and this is the crux of the paradox -- viz., a negative rather than a positive relation is generally experienced in the relations between risk and return.

This finding appears to contradict one of the standard conclusions in the literatures of finance and economics where the risk-return relationship is assumed to be positive. Furthermore, empirical work reported in finance literature has validated this positive relation, as in Cootner and Holland (1970), Conrad and Plotkin (1968), and Fisher and Hall (1969). Differences occur in the periods studied by

Bowman and these authors, however, so that one possible explanation (offered by Bowman) is that his study covered a period of disequilibrium, in which case his findings refer to short-term results which will presumably be corrected over a longer period of time.

Other explanations are also offered by Bowman but these are not fully developed by him and so we pass on to still other considerations, with other comments by Bowman to be handled as appropriate in the other studies we will cover. It is true that the "risk averse attitudes" generally assumed in the finance literature require a positive relation between risk and expected return. But these are *ex ante* considerations whereas Bowman's results are obtained from *ex post* data. Neither in finance nor elsewhere can a guarantee be offered that an *ex ante* expected return will actually be realized and so the *ex post* realizations observed by Bowman do not necessarily invalidate the assumption of a positive relationship between *ex ante attitudes* toward risk and return.

Another problem in Bowman's study resides in his use of variance as a risk measure. As Byrne (1971) notes, "one of the reasons behind the popularity of variance as a measure of risk is its tractability [and familiarity] rather than its theoretical appropriateness. There is ... evidence reported in the literature that risk tends to be viewed as asymmetric -- riskiness is a downside phenomenon -- whereas variance is a symmetric measure, with as much upside as downside value around the mean."[5]

Bowman's controversial findings did stimulate researchers in strategic management to study risk and its relationships to other relevant constructs. For example, using the same methods as Bowman, i.e., two-by-two contingency tables, and the same "association ratio", Figenbaum and Thomas (1986) examined risk-return relationships in their study on the dynamic behavior of these relationships over time. In place of just one measure of risk, however, Figenbaum and Thomas used the following two: (1) variance of ROE as determined from accounting data and (2) a systematic risk measure, β (= beta), defined and discussed below, with its value determined from market data. Using Bowman's

[5] For the variance to be an appropriate measure of risk it is generally necessary to assume that the mean is an appropriate measure of return.

"association ratio" for each 5 year time period from 1960 to 1979, Figenbaum and Thomas found that when risk and return were measured by accounting data the risk-return relationship was contingent upon environmental factors, with the risk-return relationship being positive in stable environments (1960-1964, 1965-1969) and negative in turbulent (uncertain) environments (1970-1974, 1975- 1979). They also found evidence from their use of accounting data partially supporting Bowman's paradox in that positive relationships of risk and return were observed for high performance industries but negative relationships for low performing industries.

For their accounting data, Figenbaum and Thomas used only annual data so that they had only 5 observations in each of the periods they studied while (in conformance with the finance literature) they used monthly data to calculate their β values so that in this case they used 60 observations for each 5 year period.

For market-related risk and return measures, Figenbaum and Thomas used the average of 60 month (5 year) market return data, including ordinary dividends, derived from the CRSP (Center for Research in Security Prices) data base. Proceeding in this manner, they first obtained *beta* values for the so-called "systematic risk" for each firm by means of ordinary least squares applied to the formula proposed in the "capital asset pricing model"[6] as found in the financial literature, and then used the median of market return and the median of the βs for each industry to construct two-by-two contingency tables to examine the association ratio. Following a suggestion by Bowman (1980), Figenbaum and Thomas tested the proposition that "*using a market-based risk measure (such as beta from the capital asset pricing model) will mask the firm-level risk-return paradox. The 'perfect' market will both compensate for and mask the effects of the risk-return paradox.*" They found that the evidence was consistent with this proposition and the evidence did not support the risk-return paradox in capital markets.

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[6] See expression (2) below and the more detailed discussion of (26) ff. A concise discussion of "systematic risk" and other concepts related to the "capital asset pricing model" in finance may be found on p.82 in Cooper and Ijiri (1983).

Evidently the use of market data led Figenbaum and Thomas to results that differed from those which they obtained from accounting data. This may be accounted for in part by the use of two different measures of return: (1) ROE as obtained from accounting data and (2) market return as measured by stock prices and dividends. As noted above, the data treatments also differ in that only 5 points were used for the accounting data while 60 observations were used in the market data components of this study. Five data points do not seem adequate to establish what is claimed for risk-return relations being contingent on environmental conditions and, in addition, Ruefli (1988) has shown that there are problems of statistical identification that need to be dealt with explicitly in order to establish such relationships. In particular, Ruefli (1988, p.27) notes that "the reports in the literature of negative [or positive] mean-variance relationships most likely have arisen from "misidentification" of the nature of the association between mean and variance with the effects of shifts in that relationship over time."

In a more recent article, these same authors, Figenbaum and Thomas (1988), used a different approach in which they adopted the "Prospect Theory" proposed by Kahneman and Tversky (1979).[7] To examine risk-return relationships in this study they utilized Spearman's rank correlation coefficients in addition to the association ratios. "Prospect Theory" distinguishes between the behavior of firms experiencing below target level performance and firms experiencing performance which is at or above their target levels and, in accordance with that theory, Figenbaum and Thomas found that a negative risk-return relationship tended to characterize the behavior of firms with below-target level performance, and a positive relationship tended to characterize firms with above-target level performance. Target level was measured in terms of the industry median of return on equity. However, industry medians need not conform to the target return levels (aspiration levels or safety levels) for each firm as the (single) critical point determining risk attitudes of individuals in Prospect Theory. Instead of devoting adequate attention to this topic, Figenbaum and Thomas proceeded to continue to measure

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[7] Bowman (1982, 1984) also uses prospect theory which he couples with content analysis of corporate annual reports to detect possible differences in risk averse, risk seeking and risk neutral behavior by firms under different conditions.

risk by the variance of average return and the same division into "high" vs. "low" was used to dichotomize the data by reference to the median for use in two-by-two contingency tables and then to calculate an "association ratio" of risk-return relations in a manner similar to that used by Bowman.

Another stream of risk related researches in strategic management has centered around studies of the risk and return differences across "diversification strategies". Bettis and Hall (1982) examined the risk-return relationship in diversified firms where risk was measured by variance of accounting ROA (Return on Assets) and found that a significant negative relationship existed for firms pursuing a "related-link" strategy [8] while significant positive relationships existed for firms using an "unrelated" strategy. Bettis and Mahajan (1985) also explored the risk-return performance in diversified firms. Clustering was used to identify different levels of diversified firms by their levels of risk and return performance, where ROA averaged over a 5 year period was used for return and variance of ROA for this same 5 year period was used for risk. Bettis and Mahajan found that similar risk-return patterns could result from different diversification strategies and a performance displaying high-return and low-risk was not guaranteed by adaptation of a "related" diversification strategy. Hoskisson (1987) examined the relationship of return and risk for firms possessing multidivisional structures and using a diversification strategy. He found that implementation of a multidivisional structure in unrelated-diversified firms both reduced risk (as measured by variance of ROA) and increased return. The findings of Hoskisson (1987), coupled with those of Bettis and Mahajan (1985), thus implicitly support the Bowman risk-return paradox by identifying a certain group of firms which exhibited high return and low risk in their behavior and another group of firms with high risk and low return.

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[8] This term is taken from Rumelt (1974) who extended Wrigley's (1970) four diversification strategy categories (*single*, *dominant*, *related*, and *unrelated product*) into 9 sub-categories: *single*, *dominant-vertical*, *dominant-constrained*, *dominant-linked*, *dominant-unrelated*, *related-constrained*, *related-linked*, *unrelated-passive*, and *acquisitive conglomerates*, according to product diversification. *A related-linked* strategy is a sub-category of *related* diversification strategy in which firms have less than 0.7 specialization ratios, and related ratios of 0.7 or more. See Rumelt (1974) for detailed discussion.

Unlike the above findings which were supportive of negative risk-return relationships, Cool and Schendel (1987) failed to find significant risk differences among strategic groups.[9] In their study, three sets of performance measures were utilized in the form of market share, weighted segment share (a measure of dominance in market segments), and inflation adjusted returns on sales. As risk measures, standard deviations of these performance variables were used. Using this information Cool and Schendel noted that "risk may be firm-related, rather than a function of the type of strategy employed, and may have to do with the *match* between *past* commitments of scope and resources and *currently* pursued strategic actions, rather than just current commitments alone." They also commented that "while in equilibrium conditions risk-return relationships of strategic actions should be positively related, negative relationships may be observed in states of disequilibrium."

In contrast to these findings of seemingly negative or insignificant relationships between risk and return in this literature, other literatures report findings of positive risk return relationships. In finance, especially, it is an almost unchallengable paradigm that positive risk-return relationships generally prevail -- in conformance with the assumption of a generally prevailing *ex ante* risk averse propensity. For further discussion, see Cootner and Holland (1970) or Conrad and Plotkin (1968). Nor is this finding confined to the finance literature. Bettis (1981), in his work on performance differences in diversified organizations, found that risk measured by the standard deviation of return on assets was positively related to return in diversified firms and that there were no significant risk differences across diversification strategies. Cardozo and Smith (1983), also found that the correlation between return (ROI: Return on Investment) and risk (measured by the standard deviation of ROI) was positive and significant. Neumann, Bobel and Haid (1979), in their study on the relationship of profitability to risk and market structure in West Germany, found a positive risk-return relationship and a negative relationship of risk to two firm size measures: relative firm size as measured by dividing a firm's sales by an industry average sales, and absolute firm size as measured in terms of the logarithm of the total value

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[9] The idea of strategic groups appears to have been introduced by Hunt (1972). Following along these lines Cool and Schendel (1987) define a strategic group as "a set of firms competing within an industry on the basis of similar combinations of scope and resource commitments."

of a firm's assets. Armour and Teece (1978) explored a risk-return relationship within the framework of multidivisional structures and found a negative but not statistically significant association between risk measured by the variance of return on equity (ROE) and return.

Using different data and different time periods, Marsh and Swanson (1984) re-examined Bowman's paradox and with few exceptions (machinery, and real estate industries) failed to find any significant risk-return relationship for the industries they studied. Further, these two exceptions, i.e., machinery and real estate, showed a positive relationship rather than a negative relationship. In addition to using several different measures of return and risk, Marsh and Swanson introduced a distinction between equilibrium and non-equilibrium behavior in risk-return relations which they stated as follows.

> In the absence of some impediment, an equilibrium should be reached in which the positive relation between risk and expected return on stocks reflects the relationship between risk and return on firms' marginal projects. An empirical result that, across firms, lower risk projects yield, on average, high expected returns would certainly constitute an anomaly, if not a paradox, from an equilibrium point of view (Marsh and Swanson, 1984, p.35).

However, beyond introducing this conceptual distinction, Marsh and Swanson do not provide answers to questions like the following: given a position of high return and low risk can we be sure that this is an equilibrium position and does this eliminate the possibility of movement to still better risk-return relations? Such issues are important and need to be addressed for a use of such findings in strategic management planning. Moreover, even for use in public policy, only crude qualitative characterizations and classifications are possible with reference to theoretical positions and/or the assumptions used in the literatures of finance and economics until answers to questions like these are available.

As reviewed above, risk in strategic management is usually measured in terms of variance or standard deviation around return, with the latter being measured by various averages such as average of ROA, ROE, ROS (Return on Sales), etc., at or across a specified period of time. Rationales for the use of "variances" or "standard deviations of return" around these average measures can be found in work by Beaver, Kettler and Scholes (1970).

Comparing market risk(β) with various risk measures[10] obtained from financial statements these authors showed that accounting risk measures, especially earnings variability (variance measure of risk), are highly correlated with market risk measures such as the β s used in CAPM (Capital Asset Pricing Model).[11] They also found that accounting risk measures could be used as instrumental variables to provide superior forecasts of the market determined systematic risk as measured by β by reducing or eliminating the errors in the observed β. From these findings, Beaver, Kettler and Scholes concluded that accounting risk measures could be used as a proxy for market risk (β) when market risk is not readily obtainable. Another reason advanced for the wide use of variance of returns as risk surrogates is that these measures can reflect other risks besides market risk when managers need to consider other things besides the systematic market risk reflected in β (Aaker and Jacobson, 1987).

In the context of strategic management planning, however, there is another point to consider in that risk may be multi-dimensional in character and cannot be reflected adequately by a single measure such as the variance of a return. Even researchers in finance and economics like Baumol (1963) have explicitly criticized the use of variance as a risk measure to represent investment-related risk adequately. Findings of risk-return relationships of a perverse or paradoxical nature could have resulted from the application of inappropriate measures of risk and this, in turn, may stem from the lack of clear and operationalizable definitions of risk relevant to the context of strategic management planning. The topics of risk and measurement of risks will therefore begin to be addressed explicitly in the sections that follow.

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[10] Risk measures compared are earnings variability (standard deviation of an earnings-price ratio), earnings covariability (an accounting β computed in a manner similar to market β), dividend payout, growth, leverage, liquidity. See Beaver, Kettler and Scholes (1970) for further detail.

[11] See next section for discussion.

2. Studies Using Other Measures of Risk

A measure of risk which is extensively used in the literature of strategic management is "systematic risk" as defined in the Capital Asset Pricing Model from the finance literature. Systematic risk is, in general, measured by the estimated value of the β coefficient in the following Capital Asset Pricing Model formula:[12]

$$R_j = R_f + \beta_j[R_m - R_f]$$

$$\text{with } \beta_j = \frac{Cov(R_m, R_j)}{Var(R_m)}. \tag{2}$$

As used in the finance literature R_j is the required return on asset j, R_f is the return on a risk-free asset, and R_m is the return on a market portfolio of securities.[13] The term Cov (R_m, R_j) refers to the covariance of market return and the return on security j and Var (R_m) represents the variance of the market return. Thus β represents a measure of the *relative* volatility of a stock as it moves up or down relative to the general market. It is assumed in the finance literature on this topic that unsystematic risk can be eliminated by diversification so that only systematic risk, as represented in the above formula, is relevant to determining the required rate of return on security j.

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[12] See (26) ff., below, for a more detailed discussion or see Cooper and Ijiri (1983, p.82) for a brief discussion of the rationale for CAPM (= Capital Asset Pricing Model).

[13] R_f is generally measured by the rate of return on Government bonds or Treasury bills and R_m is typically measured in terms of the Standard and Poor's Index of common stocks or average rate of return for all NYSE securities. See, e.g., the risk-return ratings used by *Business Week* in its evaluations of Mutual Funds as described in section VII, below.

Using systematic risk (β) or various other measures of market-based risk as a measure, Montgomery and Singh (1984), Lubatkin and O'Neill (1987) and Barton (1988) investigated relationships of systematic risk and diversification strategies. Montgomery and Singh (1984) investigated the associations of different diversification strategies categorized by Rumelt (1974) with systematic risk and found significantly higher systematic risks for unrelated diversification strategies compared to other diversification strategies, i.e., single, dominant, related constrained, related linked (see footnote 8 above). They believe that the higher systematic risk for unrelated diversifiers is due to the low market power, low capital intensity, and high debt position of firms using an unrelated diversification strategy. Barton (1988) explicitly examined differences among systematic risk, market power, capital intensity, and debt position across diversification strategies and found supportive evidence for Montogomery and Singh's explanation. In addition, Barton also found that the relationship between the financial variables [14] and systematic risk varied with diversification strategies.

Lubatkin and O'Neill (1987) examined the relationship between merger types and three risk measures in the form of systematic risk, unsystematic risk and total risk using monthly market data from the CRSP data base. Estimation of systematic risk and unsystematic risk were obtained by means of ordinary least squares in the same spirit as Aaker and Jacobson (1987), and total risk was measured by the total variability of a security's return. Lubatkin and O'Neill (1987) classified merger strategies into four types, viz., single-business, vertical, related, and unrelated merger, according to the strategic relationship that appeared to obtain between the acquired firms and the acquiring ones. They then related these types of merger strategies to each component of risk and found that regardless of merger types the unsystematic risk of acquiring firms increased. Among the four types of mergers, only acquiring firms with related merger strategies were found to reduce both systematic risk and total risk.

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[14] Market power was measured by profitability, capital intensity by the average of net fixed assets divided by total book assets, debt position (financial leverage) by the average ratio of equity to capital invested.

In its origin the β risk measures of modern finance theory were utilized as convenient ways to deal with data from the securities markets and to examine the decision-making attitudes and criteria of stockholders. Under the assumption that stockholders can always eliminate unsystematic risk (i.e., the firm-specific risk) by diversifying their portfolios, systematic risk (β) is regarded as the criterion to be employed in investment decision-making. Risk-averse stockholders will require a risk premium to induce them to choose risky stocks. Accordingly, the relationship between risk and return is expected to be positive so that, correspondingly, β will be positive in the above formula.

The above characterizations are not intended to apply (or at least do not appear to apply) to situations in which stock purchases bear on corporate control issues such as those involved in mergers, acquisitions, and divestments. Nevertheless, analogies are employed so that, like investors in securities, diversified firms could also eliminate their unsystematic risk, at least to some extent, by diversification of the firms under their control. Less-diversified firms or firms which are not diversified will experience systematic as well as unsystematic risk. Even if we remain with the variability of security returns, there are other issues that remain to be addressed in considering corporate strategies of diversification as they relate to risk. Thus, if total risk is defined as the sum of systematic risk plus unsystematic risk we could not expect this relation to maintain unless a diversified firm possessed a portfolio of subsidiaries (and related firms) which was representative of the total market risk. It is not even clear how such a strategy could be implemented without something like a market in *all* firms being available in a form that includes control and direction of their activities (e.g., for strategic planning purposes). For less-diversified firms a use of β to estimate systematic risk would underestimate their total risk.

There have been numerous researches in various areas that have dealt with the importance of unsystematic risk and total risk.[15] These studies, which have appeared in different literatures, include the

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[15] The sum of systematic and unsystematic risk is not necessarily equal to total risk of return variance. For example, in the "diagonal" model (Sharpe, 1963; Lintner, 1965), which is a simplified form of CAPM, this association is expressed by the following formula: $\sigma^2(R_i) = \sigma^2(e_i) + \beta_i^2\sigma^2(R_m)$ so that total

following: Mintzberg (1979) in organization theory, Fama (1980), and Jensen and Meckling (1976) in agency theory, Amihud and Lev (1981), and Eger (1983) in the finance literature, as well as the studies by Aaker and Jacobson (1987), and Lubatkin and O'Neill (1987) in the strategic management literature.

Using the PIMS data base of the Strategic Planning Institute, Aaker and Jacobson (1987) used ROI (return on investment) for their measure of return and then used the CAPM described above to estimate both systematic and unsystematic risk by means of ordinary least squares. This was done for each of 1376 firms for which 5 to 13 annual data points were available in PIMS during the period of 1970 - 1983. Using the deviation of ROI from the long-term rate on government bonds, systematic risk was measured by β and unsystematic risk was measured by the standard deviation of the residuals from the regression represented in (2). Using these estimates Aaker and Jacobson regressed ROI against their measures of systematic and unsystematic risk and found ROI to be more strongly affected by systematic risk than by unsystematic risk. Both regression coefficients showed positive risk-return relationships. As already noted, the correlation between ROI and systematic risk is posited to be positive and highly significant in the finance literature. The relation between ROI and unsystematic risk, which is assumed to be zero in the finance literature, is found to be significant across all business by Aaker and Jacobson but is found to vary when these businesses are subdivided into consumer goods and capital goods producers -- being positive and significant for the first group and positive, but small and insignificant for the latter group.

Other measures of risk and return are also used in the finance and economics literature. Benishay (1961), for example, turned to a use of *leverage* as a measure of risk by reference to debt-to-equity ratios. The leverage dimension of risk has also been widely used and studied in terms of its relations to other measures like variance of return in studies reported by Gale (1972), Stigler (1963), Hall and

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risk $\sigma^2(R_i)$ consists of the sum of the error variance of security i's return, which is not a linear function of R_m, plus the variance of the market rate of return modified by the square of β as a measure of systematic risk. See Beaver, Kettler, and Scholes (1970).

Weiss (1967), and Caves (1970). Although rarely utilized in the strategic management literature [16] the use of debt to equity ratios or similar measures of leverage would seem to merit attention because they tap another dimension of risk in the form of the possible loss of control of the entire entity.[17]

Singh (1986) utilized a "structural equation model" to examine direct and indirect relationships among performance, risk taking, slack, and decentralization. As a measure of risk-taking attitudes, Singh used a composite index from a 7 point Likert scale in a questionnaire composed of 6 items. Top managements were asked to rate their organization's orientation to risk taking in 6 different decision situations, such as innovation reliance, debt-financing, R & D, investment on high risk and high return alternatives vs. low risk and moderate return options, etc. For performance measures, Singh used both financial performance (as measured by return on net worth and ROA) and subjective performance measures obtained from replies of top executives to his questionnaire. Singh found a negative risk-return relationship for firms with *below acceptable* performance -- where performance was identified by three performance measures (return on net worth, ROA, and the subjective performance measure obtained from his questionnaire returns). However, in terms of his structural model a positive relationship was found between performance and risk taking, when organizational slack or decentralization played a mediating role. Unlike much of the other research on risk in strategic management, Singh investigated *ex ante* behavioral aspects of risk attitudes and their relationship to performance along with achieved (*ex post*) data which he obtained from a previous study on risk taking by Khandwalla (1976, 1981). As already noted, this approach by Singh is unusual in that risk attitudes are determined in most other studies on risk in strategic management by examining only the *ex post* risk-return relationships -- which means, in turn, that all such studies are subject to the pos-

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[16] An exception is Amit and Livnat (1988a, 1988b).

[17] This topic of loss of control as a dimension of risk has also tended to be ignored in much of the literature of classical economics. See W. W. Cooper, "Theory of the Firm: Some Suggestions for Revision," *American Economic Review*, XXXIX, 1949, 1204 - 1222.

sibilities of logical errors of inverse inference when explicitly or implicitly trying to reason from *ex post* results to *ex ante* attitudes toward risk.

3. Studies Using Multiple Measures of Risk

Amit and Livnat (1988a), utilizing two different concepts of risk in the form of operating risk and financial risk, examined "risk-return trade-offs" across diversification strategies. For operating risk, they used three measures of profit variability. One was profit variability as measured from accounting data by the standard deviation of "funds from operations" divided by total assets.[18] The other two measures of operating risk were "systematic risk" and "total risk" obtained from market data, where total risk was measured in terms of the standard deviation of daily return on the security of each firm and systematic risk was estimated by an ordinary least squares regression using the conventional expression in (2) for the β calculation. For financial risk, Amit and Livnat used leverage as measured in terms of the debt ratio (total debt divided by total assets). They found negative relationships between risk and return using accounting data and leverage. From market data they also found a negative relationship between market return on securities and the standard deviation of daily return as a measure of "total market risk" but, a positive association with systematic risk as measured by β was observed.

Turning to a different method Amit and Livnat in this same article used a cluster analysis approach to divide firms into 4 categories from high return-high risk down to low return-high risk. Clustering on returns in the form of returns from operation and risk in the form of the standard deviation of these values, they arrived at somewhat different results from those of Bowman (and others) and found that the cluster for low return and high risk contained less than 20% of the firms studied. Thus, in contrast to Bowman, they found that, in general, a positive risk-return relationship was maintained.

[18] In calculating "the funds from operation," Amit and Livnat (1988a) moved from an income-statement to a funds-flow statement point of view.

Woo (1987) used 3 risk measures which consisted of (1) "share instability" measured by the deviation from the market share for sales trend of a firm and (2) "price-cost gap" (the difference between price growth and cost growth) as a risk measure in addition to (3) ROI (return on investment) variation. "Market share instability" was used as a measure of "uncertainty in market share position", and the "price-cost gap" as a measure of the price control capability of a firm confronted with cost increases (Woo, 1987, p.155). This approach by Woo can be interpreted as an attempt to relate marketing strategy measures and considerations to company strategy objectives and risk dimensions with the latter being characterized only in the form of ROI variations. In any case, Woo's study is included here because it uses multiple measures (as was the case for the other studies covered in this section) in order to recognize that risk is not necessarily a uni-dimensional concept.

III. Separation of Risk - Reward Structures

Extensive studies of risk - return relationships may be found in many other literatures such as the literatures of decision theory, economics, and psychology where studies of utility theoretic approaches, have been much influenced by the formulations in von Neumann and Morgenstern's *Theory of Games and Economic Behavior* (1947). An excellent evaluative survey of this literature may be found in Schoemaker (1980)[19] who implicitly suggests that resolution of the paradoxes and failures encountered in tests of behavior to accord with the expected utility theory of von Neumann and Morgenstern and their followers may be facilitated if the rewards and risk structures are separated in place of the interwined forms in which they occur in the "lotteries" that, at present, constitute a central part of this theory. As Schoemaker (1980) notes (p.137) "... the outcome space concerns the way in which the EU model [i.e., the expected utility model] combines a person's risk-taking attitude into one measure." This is a follow-up to other statements in Schoemaker (1980) who notes that a good deal of indeterminacy in model testing and validation has resulted from the way risks and re-

[19] See also Paul J. H. Schoemaker, "The Expected Utility Model: Its Variants, Purposes, Evidence, and Limitations," (1982), pp. 529 - 563 and/or S. Friar (1986).

wards are combined in these models -- e.g., (Schoemaker, 1980, p.27) "Although an EU defender may note that most of the paradoxes and violations involve the probability side, not the value side [in the various experiments designed to test this theory] , the two are so inextricably mixed in the von Neumann and Morgenstern [model] that distortions in either would invalidate the model...."

Here we propose to undertake a development which will generally separate risks from rewards by means of chance constrained programming models. This will be accomplished by following a strategy in which risks are represented as constraints (which are to be satisfied) and rewards are represented in the objectives (which are to be pursued). Such a separation can offer advantages not only for conceptual clarity but also for use in strategic management planning *provided* a mechanism is also supplied which can be used to relate risk s to rewards.

To start with, it is useful to turn to the literatures of insurance where Lalley (1980)[20] in a work directed to an audience of professional risk managers describes risk in the classical insurance sense as being "the chance of loss." More generally, we may think of the following as a definition to guide our development.

risk = chance of occurrence of an unfavorable event.

This definition is readily extended to the plural, *viz.*, "classes of events and their related chances of occurrence," and it may be iterated to accommodate different levels and dimensions with possibly different measures to be used in order to represent each of several different risks to be considered.

We will interpret the word "chance" as meaning "probability of occurrence", as in the statement by the Dutch government (after the 1953 flood) that all sea dikes to be built should satisfy the following con-

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[20] See Edward P. Lalley, *Corporate Uncertainty & Risk Management*, Risk Management Society Publishing, Inc., New York, 1982. See also *The Dictionary of Insurance Terms*, R. H. Blanchard (ed.), Chamber of Commerce of the United States (1949).

dition: the probability that at any time in a given year the sea level will exceed the level of the dikes is to be 1:10,000 or less. Quoted from Dekkers and De Haan (1987), it is apparent that the "levels" as well as "chances" of occurrence of such an event need to be considered since a "one-inch excess" and a "one-foot excess" can have drastically different consequences. This is to say that the levels as well as the chances of occurrence must both be capable of treatment in the planning models utilized. (See (7) below)

For an example of how risk may be dealt with in a management planning context we may turn to the original application which gave rise to the ideas of chance constrained programming. These ideas were developed in the concrete context of responding to the challenge of designing a model for scheduling heating oil production at Standard Oil of New Jersey. The following constraints incorporate some of the applicable policy conditions on risk which had to be satisfied for any production to be considered acceptable:

$$
\begin{aligned}
&Pr[I_0 + R_1 \geq S_1] \geq \alpha_1 \\
(3) \qquad &Pr[I_0 + R_1 + R_2 \geq S_1 + S_2] \geq \alpha_2 \\
&\qquad \cdots\cdots\cdots \\
&Pr[I_0 + \sum_{j=1}^{n} R_j \geq \sum_{j=1}^{n} S_j] \geq \alpha_n
\end{aligned}
$$

where "Pr" refers to "probability" and the other terms are defined as follows:

I_0 = Initial inventory

(4) R_j = Amount planned for production of number two heating oil in period j = 1, 2,..., n

S_j = Sales demand for number two heating oil in period j = 1, 2,..., n.

To be noted is that the S_j which represents sales demands in period j = 1, 2, ..., n are all random variables whose values are not known at the time the refinery schedules are to be set. Hence the desired policy of satisfying these demands can be prescribed only in terms of the probabilities noted by the $0 \leq \alpha_j \leq 1$ with a "risk" of failing to meet the demand in period j therefore set at $0 \leq 1 - \alpha_j \leq 1$.

This model was selected to show why it is desirable to extend the definition of risk beyond the insurance industry interpretation in which the occurrence of losses represents the only type of unfavorable event to be considered. In this application to heating oil production scheduling, the risk of being unable to satisfy customer demands was an important management consideration (even though no financial loss need be associated with an inability to satisfy all of this demand) because "heating oil" was regarded by the management of Standard Oil of New Jersey as a product "charged with a public interest." In other words, from a public policy point of view, i.e., from a "total company standpoint," management considered it highly desirable to avoid possible negative public reactions because of a failure to meet customer demands -- demands which might even be "excessive" (and possibly result in monetary losses if met) in a spell of cold weather.[21]

Here we need to note that the above constraints are multiple in character with different $0 \leq \alpha_j \leq 1$ choices possible in different periods $j = 1, 2, \ldots\ldots, n$ as company policy and strategy might decide for the schedules -- and risks of not meeting demands -- at different times of the year. Other constraints also had to be considered which bear on the company's total production and storage capacities but we will not discuss them here.[22] In any case whatever company policies might be stipulated it is also desirable to provide ways to evaluate alterations in whatever α_i risks might be imposed and to study possible consequences of varying these risks (of not being able to meet all demands), at least within limits that the company might believe it could justify. To start an analysis to see how this might be

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[21] Standard Oil of New Jersey was the world's largest supplier of heating oil at the time this model was developed.

[22] See Charnes, Cooper, and Symonds (1958). See also the distinction drawn between "policies" and "rules" on p.260 of this article. Briefly, a "policy" may be interpreted as a constraint or condition, e.g., a chance constraint, which permits deviations, but *not* in amounts or frequencies which attenuate or alter the policy structure as an identifiable pattern. This is accomplished in the above model by choosing values of α_i which are high, e.g., $\alpha_i > 0.5$, but less than unity. A "rule," on the other hand, is the applicable case when $\alpha_i = 1$ so that *no* exceptions are allowed.

done we first turn to the company objective which was stated as "minimize the total cost of meeting these demands under the stipulated constraints." In other words the company wanted to minimize the total costs of conforming to these policies.

That is, total cost or, more precisely, total expected cost, is the "figure of merit" to be used to judge any program and the objective is to minimize this figure of merit.[23] Mathematically this objective can be formalized as:

$$\min E\sum_{j=1}^{n}[c_j R_j + k_j \bar{I}_j]$$

(5) where

$$\bar{I}_j = \frac{[I_{j-1} + I_j]}{2} = \text{average amount of inventory in period j}$$

$$k_j = \text{unit inventory carrying-cost in period j}$$

$$c_j = \text{cost of producing a barrel of heating oil in period j}$$

where the c_j and k_j are random variables and E refers to "expected value." In words, the "objective is to minimize the total expected costs of meeting the demands."

This way of approaching the problem, as we now note, accomplishes a separation between "risks" as represented in the constraints (3) and the "objective" to be pursued as represented in (5).

In the course of developing this approach for scheduling heating oil production it became apparent that a systematic procedure for setting these risk levels was needed as they were to be selected for use at different times of the year. For the first time in its history the Standard Oil Co. therefore set up a committee to effect such risk evaluations and to estimate their expected costs and benefits as a basis for management planning decisions in this important class of products. The thus estimated costs could then be matched with the different refinery schedules needed to meet the seasonally de-

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[23] We are here using the terminology introduced and defined in Chapter I of Charnes and Cooper (1961).

pendent demands at the various α_i levels that were considered to be practically justifiable. The recommendations from the "risk recommendation committee" were then submitted to another committee esponsible for setting scheduling policies in order to secure conformance to the total manufacturing plan.[24] See Charnes, Cooper and Mellon (1954) for a discussion of refinery running plans and how different products may be fitted into a total plan.

IV. E Models

We now turn to a more general formulation for use in evaluating risk-return possibilities while retaining an approach which separately identifies "risks" with constraints and "rewards" with objectives. To start this development we begin with the following more general version of a chance constrained programming model:

$$
\begin{aligned}
&\max E\sum_{j=1}^{n}\pi_j x_j \\
(6) \qquad &\text{subject to} \\
&Pr[\sum_{j=1}^{n}a_{ij}x_j \le b_i] \ge \alpha_i\,, \quad i = 1, 2, \ldots\ldots, m \\
&x_j \ge 0\,, \qquad j = 1, 2, \ldots\ldots, n
\end{aligned}
$$

where the non-negative x_j are decision variables with values to be chosen. For the present the a_{ij} are to be considered as structural constants and treated as givens that relate the jth decision variable to

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[24] This included the possibility of altering the scheduling plans for other products besides heating oil. The study that led to the original development of chance constrained programming was under the direction of G. H. Symonds who served as chairman of the manufacturing technical committee and was therefore responsible for keying others into how the plans were to be effectuated. See G. H. Symonds (1955).

some collection of $i = 1, 2, \ldots\ldots, m$ processes, while b_i is to be regarded as a random variable (e.g., a limitational condition) applicable to the *ith* such process.

Here we have replaced the unit costs c_j in (4) by unit profits, π_j. The objective of (6) is thus oriented toward maximizing the figure of merit given by expected total profit, with this optimization to be accomplished while satisfying the constraints at "reliability levels" prescribed by the values $0 \leq \alpha_i \leq 1$ which are assigned to each of these $i = 1, 2, \ldots\ldots, m$ constraints.

It should perhaps be noted that these variables and values can be given a variety of interpretations. For instance, we can think of these b_i values as being derived from an original set of random variables $\hat{b}_i$ via a relation of the form:

$$(7) \qquad b_i = l_i \hat{b}_i + \delta_i$$

where l_i is a prescribed constant (e.g., 80% or 110%) for the level of the $\hat{b}_i$ to be satisfied and δ_i represents an additive or subtractive constant such as, e.g., a minimum (safety) level which is to be added (or subtracted) from the $\hat{b}_i$ levels that may materialize. By varying these l_i and δ_i values it is then possible to study alternatives that might be prescribed for the levels at which the constraints are to be satisfied. This can be done in a manner that either trades off variations in l_i and δ_i against variations in the α_i or else studies and evaluates possible variations in both of them.

We can similarly refine the α_i values to be used as risk controls by suitably iterating the constraints. For example, in particular periods of the heating oil season as reflected in (4), we might iterate the constraints for the month of February by specifying a risk of at most 5% for falling short of meeting all demands and also specifying a risk of at most 2% of not meeting 90% of the February demand level, at wnatever value this level may materialize, and so on.

Turning to the objective in (6) we note that the π_j are random variables. Each of these random variables is associated with a particular (known) probability distribution which, for concreteness, we can associate with a particular product to be produced in an amount given by an x_j choice. Any collection of x_j choices generates a new probability distribution. Thus, the general problem stated in the objective is to determine a best choice among these various distributions. In (6) the best choice is effected by reference to the $x_1, .. x_n$ which will maximize the expected total profit subject, of course, to the risk (and other) controls imposed by the constraints. This is not the only possible objective, however, and so we examine some of the other possibilities in the sections that follow while leaving the constraints unaltered.

V. V Models and Variance Measures of Risk and Information

As noted in the opening section of this paper, the example in (6) forms a class called "E models" in chance constrained programming. Another class consists of "V models" which we represent here as follows.

$$
\begin{aligned}
&\min E[\sum_{j=1}^{n} \pi_j x_j - \bar{\pi}]^2 \\
(8) \qquad &\text{subject to} \\
&Pr[\sum_{j=1}^{n} a_{ij} x_j \leq b_i] \geq \alpha_i\,, \quad i = 1, \ldots\ldots, m \\
&x_j \geq 0\,, \qquad j = 1, 2, \ldots\ldots, n
\end{aligned}
$$

where $\bar{\pi} = \sum_{j=1}^{n} \bar{\pi}_j x_j$ so that $\bar{\pi}$ is a weighted combination of the $\bar{\pi}_j$ that represent the average expected unit profit from the jth of $j = 1, \ldots\ldots, n$ outputs. The constraints in (6) and (8) are the same but the objectives differ. This is to say that the risks being considered as allowable are the same in both models, although the different orientations in the objectives of (6) and (8) may lead to different risk choices even when facing the same risk situations (as represented in the constraints) via the different x_j choices which result from solving each of these two different models. Note therefore that the choice of an objective and associated figures of merit also needs to be dealt with along with the choice of different risk conditions which are considered to be allowable are all part of the problem of strategic management.

Our survey of the literature dealing with risk in strategic management showed a heavy reliance on the use of variance as a measure of the amount of risk. The V model given in (8) may be regarded as extending this measure for more general uses by embedding it in a multi-product or multi-activity framework with constraints that include other controls on risk. We shall shortly try to clarify this but, for the moment, we may think of constraints other than those on profits as found in examples such as the following: One constraint may represent a financial planning constraint which specifies that cash balances should not fall below a certain proportion of potential cash demands. Another constraint may specify maintenance of market positions as part of a company's marketing strategy. Each of these constraints is associated with α_i risk levels, iterated if necessary, and the same may be true for constraints such as those which are combined to conform to prescribed conditions on "payback periods" designed for use in coordinating marketing and financial planning activities. Conditions like chance constraints on payback periods can be used to coordinate other activities. They can also be used to study the effects on each of several of the thus coordinated activities -- such as the risks to be encountered for financial liquidity maintenance and market share positions in each of several periods when either the length of the payback periods are varied or when the associated $(1 - \alpha)$ risks of failure to meet payback in the stipulated periods are varied.[25]

Using the same constraints in (6) and (8), the objectives differ in ways that generally lead to different x choices. The V model is directed to the probability distribution with minimum variance, from among the available choices with, if necessary, some sacrifice in the level of expected profits that could be obtained from the E model. These E and V objectives thus correspond to the two noted by Baron Rothschild who was said to respond to a request for advice on how to invest an inheritance by asking "Do you want to eat well or sleep well?" The V model is more in accord with the sleep-well objective

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[25] See Charnes, Cooper, De Voe and Learner (1968) for interpretations of the ubiquitous use of payback periods as a control for risk and uncertainty in planning new-product marketing strategies. The use of payback periods is also ubiquitous in capital budgeting practices. See Byrne, Charnes, Cooper and Kortanek (1967) for a discussion of their uses in the form of risk constraints in association with differing objectives in capital budgeting.

in that it is oriented toward more stability and hence toward a promise of more predictability than the E model.

The variance measure used in the objective of (8) is more general than those that were used by the authors of the articles surveyed earlier in this paper. Those authors generally restricted themselves to various estimates on a one-variable-at-a-time basis, whereas the function stated in the objective of (8) handles multiple variables simultaneously in a manner that allows for their pairwise interactions. It is in fact the kind of variance used by Markowitz (1959) and others to allow for positive and negative "synergies" between the choices of securities to be held in a portfolio. These market portfolio approaches are discussed in the next section, below. Here we try to clarify the variance concept by reverting to the simpler case in which it measures the variation of each individual variable without reference to what is happening in the other variables that may be of interest.

Before undertaking this simpler development we should perhaps note that we are using the term "variance" generically to cover more general formulations such as the one in (8)[26] and we do not try to distinguish terminologically between "variance" and "standard deviations" or "standard errors," etc., when they are only different measures directed to the same concept. For instance, the "standard deviation" used in the following very simple constraint will also be referred to as "variance,"

$$(9) \qquad Pr\left[\frac{|Y-\mu|}{\sigma} \leq k\right] \geq \alpha.$$

Here μ refers to the mean associated with a random variable Y and σ is its standard deviation (=variance). The value of k and α are prescribed so that they may be parametrically varied to study possible risk choices under the conditions prescribed by the parameters μ and σ -- viz., as in the "expected return" and "variance of return" measures used by Bowman, among others, in the literature dealing with risk in strategic planning.

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[26] We also use it to comprehend still more general measures such as the "mean square errors" covered in Charnes and Cooper (1963).

The vertical strokes in (9) mean that the absolute value of the deviations is to be dealt with by these k and α choices in a manner which regards deviations above and below the mean in a symmetric fashion. The following expression relates the expression in (9) to standard statistical formulations,

$$(10) \qquad Pr[|Y-\mu| \leq k\sigma] = \int_{\mu-k\sigma}^{\mu+k\sigma} f(y)dy \geq \alpha$$

where f(y) is the density associated with the y values -- i.e., they are values of the random variable, Y -- which are to be integrated over the indicated range so that either k must be adjusted to the prescribed α value, or *vice versa.*

Now

$$(11) \qquad \int_{-\infty}^{\infty} f(y)dy = \int_{-\infty}^{\mu-k\sigma} f(y)dy + \int_{\mu-k\sigma}^{\mu+k\sigma} f(y)dy + \int_{\mu+k\sigma}^{\infty} f(y)dy = 1$$

by the definition of a density. The middle integral on the right refers to deviations in equal amounts, $k\sigma$, above and below the mean, μ. Noting that risk generally refers to downside variations, Markowitz (1959) introduced a concept that he referred to as the "semi-variance" which refers only to deviations below the mean. To obtain the probability (i.e., risk) associated with this semi-variance we can write[27]

$$(12) \qquad \int_{\mu-k\sigma}^{\mu+k\sigma} f(y)dy = \int_{\mu-k\sigma}^{\mu} f(y)dy + \int_{\mu}^{\mu+k\sigma} f(y)dy$$

---

[27] Markowitz actually uses a modified measure which we can represent as

$$(y-\mu)^{+} = \frac{(y-\mu)-|y-\mu|}{2} = \begin{cases} y-\mu \text{ if } y \leq \mu \\ 0 \quad \text{ if } y > \mu \end{cases}$$

where the vertical strokes mean "absolute value" of the difference between the value of the variable y and its mean μ. This measure reduces to the variance when the density associated with the random variable Y is symmetric. See Markowitz (1959) pp. 194 ff. for discussion.

and then note that the probability associated with semi-variance as a downside only measure is given by the first expression on the right with a suitable choice of k – e.g., choosing k=1 for a symmetric distribution.

Following this route, however, could lead to mixing risks and rewards. This can be avoided by following an alternate route in which the risks are confined to the lower tail of the distribution as in

$$(13) \qquad \int_{-\infty}^{\mu-k\sigma} f(y)dy = Pr[Y \leq \mu - k\sigma] \leq \beta$$

This way of representing risks is consonant with survey results such as are reported in Mao (1970), Petty and Scott (1981), and Crum, Laughhunn and Payne (1981a, 1981b). See also Byrne (1971) for a review of then extant surveys. See also March and Shapira (1987) for a more up-to-date discussion in which "risk" is generally regarded in terms of the chances of falling below a certain "bogey" or "target level" of return. In (13) this level is selected in a manner that relates it to σ and thus to our earlier discussion of uses of variances as measures of risk. Other ways of choosing the upper limit of this integral may be used. However $k > 0$ may be selected, it is the values that fall at or below the upper limit of $\mu - k\sigma$ that represent unfavorable events and the value of the integral in (13) is then the chance of their occurrence. Stated differently, it is the value of $\mu - k\sigma$ which defines the level at which unfavorable events begin to occur and the value of the integral in (13) provides a measure of the probability of occurrence of such an event. See our definition of risk in section III, above.

Just as different levels of unfavorable events may occur on one side of this integral so different levels of favorable events (or at least not unfavorable ones) may occur on the other side of it. We restrict the term risk, however, to the events occurring in the tail. Of course, upper tails as well as lower tails may be used. An example of risk occurring in the upper tails is provided by the heating oil model in (5) where the objective is to satisfy all demands, including very large demands at the prescribed levels of probability.

For simplicity we restrict the discussion here to models in which only rewards are included in the objective. Examples are the π_j values which represent the profits per unit which enter as random variables in the objective of both (6) and (8). From what has just been said, however, we can now begin to obtain clarification on the use of variance as a measure of risk by noting that the objective in (8) is directed to staying out of *both* tails. Thus even though the π_j are profits the objective in (8) is directed to avoiding turbulence[28] in rewards by foregoing some of the higher and as well as lower rewards that might otherwise be available. This is evidently an strategic planning objective that could be selected by a management which is interested in predictability (or smoothing) of its returns.

Returning to the chance constraints represented in (6) we can obtain still further insight into possible meanings and uses of variance. We now assume that each b_i is a random variable which is normally distributed independently of every other random variable. This provides us with access to standard statistical formulations which we use to rewrite the constraints in (6) in the following manner.

$$(14) \qquad Pr\left[\frac{\sum_{j=1}^{n} a_{ij}x_j - \bar{b}_i}{\sigma_i} \leq \frac{b_i - \bar{b}_i}{\sigma_i} \right] \geq \alpha_i$$

where $\bar{b}_i$ is the mean of b_i and σ_i is its standard deviation.

Setting $z_i = \frac{\sum_{j=1}^{n} a_{ij}x_j - \bar{b}_i}{\sigma_i}$ this condition can be replaced by

$$(15) \qquad N(z_i) \leq 1 - \alpha_i$$

where N is the standardized normal distribution with zero mean and unit variance.

---

[28] In organization theory variance of return and its variants are widely used as a measure of environmental turbulence. See, for example, Cameron, Kim and Whetten (1987), Tosi, Aldag and Storey (1973) for further details.

We do not strive for full mathematical generality but emphasize conceptual developments that allow us to relate these representations to considerations for strategic management planning.[29] This is accomplished by restricting attention to the simplest of the "decision rules" used in chance constrained programming -- *viz.*, the class called "zero order rules." Using this type of decision rule and assuming that our x_j choices will not disturb any of the densities associated with the b_i we can replace (15) with

$$\frac{\sum_{j=1}^{n} a_{ij}x_j - \bar{b}_i}{\sigma_i} \leq N^{-1}(1 - \alpha_i) \tag{16}$$

where $N^{-1}(1 - \alpha_i)$ is the fractile value associated with $1 - \alpha_i$.

Insert Figure 1 around here

For an arbitrary statistical distribution, as in Figure 1, the fractile value is set at $z_i^o = F_i^{-1}(1 - \alpha_i)$ defined as the smallest value of z_i which satisfies $F_i(z_i) = 1 - \alpha_i$. Thus, from (16) we have

$$\sum_{j=1}^{n} a_{ij}x_j \leq \bar{b}_i + \sigma_i N^{-1}(1 - \alpha_i) = \bar{b}_i + \sigma_i z_i^o. \tag{17}$$

This is an ordinary linear inequality with $\bar{b}_i$, the mean of the b_i, being adjusted upward for the z_i^o value associated with $N^{-1}(1 - \alpha_i)$ and for σ_i which is the "inverse" of the "Fisher measure of information."[30]

To interpret this pairing of risk and information measures we may note that σ_i represents the amount of information that each realization of b_i can be expected to provide on the mean $\bar{b}_i$ with which it is

[29] For a fully rigorous development see Charnes and Cooper (1963).

[30] As first introduced in R. A. Fisher (1925). See also p.58 in Kempthorne (1962) for a simplified development and discussion of the use of this measure of information in statistical analysis.

To interpret this pairing of risk and information measures we may note that σ_i represents the amount of information that each realization of b_i can be expected to provide on the mean $\bar{b}_i$ with which it is associated,[31] at least for the case of normal distribution. A large variance then means that each realized value of b_i supplies little information on the value of $\bar{b}_i$ as compared to smaller variances with, in the limit, each b_i supplying the exact value of $\bar{b}_i$ when the variance goes to zero.

It is possible, of course, to associate variance as a measure of lack of information with risk in some circumstances but care needs to be exercised in doing so. A distribution with large probabilities of unfavorable outcomes might have a very small variance, for example, and it hardly seems reasonable to associate this situation with one of small risk. The constraint in (17) will generally provide a better representation in that both risk and information are explicitly taken into account as adjustments in the form of a "safety factor" or allowance to be added to the mean. Thus both a measure of risk in the form of α_i (and its inverse, $F_i^{-1}(\alpha_i)$), and a measure of information (and its inverse, σ_i), are separately identified for evaluation.[32] Guides to action are thus once more provided which can be used with respect to both information and/or risk by (once more) studying their tradeoff consequences for the objectives in either (6) or (8).

VI. Satisficing with P-Models and E-V Equivalents

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[31] As shown by Brockett (1988), a use of variance as a measure of risk may give undesirable results even in the case of symmetric distributions.

[32] The methods for evaluating the α_i have already been described. Evaluation of the value of varying information will generally need to consider variations in sample sizes which we do not discuss in this paper. See Jagannathan (1985) for a discussion of how this may be accomplished in chance constrained programming.

Having now examined expected value and variance optimizations we next show how the two may be combined and considered in a jointly determined objective. This will be done via the P-model of chance constrained programming which can be developed in a way that relates it to the satisficing models of H. A. Simon (1957) and thus to the literature of psychology and organization theory. After this has been accomplished we shall then show how the same P-model can be used to provide contact with CAPM and other parts of portfolio theory. This will then allow us to return to our earlier discussions of the work of Bowman, et. al. from a different perspective. It will also allow us to indicate how portions of our analyses may be brought to bear in contexts ranging from applications to *ex post* data and extending to full-scale uses for *ex ante* planning.

To initiate this development we now introduce the following for use in place of an E or V objective,

$$(18) \qquad \max Pr\left[\sum_{j=1}^{n} \pi_j x_j \geq \pi^*\right].$$

Here π^* refers to a weighted combination of aspirations to be attained (or exceeded) in each of the j activities to be considered. Verbally stated, the objective in (18) is to choose x_j values which will maximize the probability of attaining this value of π^* . This is more precisely characterized by saying "among the probability distributions generated by these x_j choices the one to be selected should maximize the probability of attaining π^*" -- but, of course, the allowable x_j choices must satisfy the risk (and other) constraints as was done with (6) and (8). One possible choice would set π^* equal to the mean, as was done in (8), and thus retain direct contact with work like that described in Lev (1969) and Figenbaum and Thomas (1986). See also Bowman (1982, 1984). We proceed in a somewhat different manner, however, in order to make contact with the psychological literature from which "aspiration level theory" and subsequent developments have emerged.

The classical psychological literature on aspiration level theory[33] is couched in a deterministic manner which cannot easily be used in interpreting the risk formulations that are wanted for strategic management planning. To some extent this deficiency is now being repaired as in the work by Payne, Laughhunn and Crum (1980) which joins work from the decision theory literature, as in Fishburn (1977), with recent literature in psychology like that represented by the work of Kahneman and Tversky (1979). Unfortunately even these developments are also of limited use because they are generally confined to what John Pratt (1988) refers to as "one risk situations" whereas what we require is ready access to a use of multiple (possibly even contradictory)[34] risk constraints.

Turning to some of the behavioral approaches to *organization* theory we can obtain further perspective on what is required by reference to treatments such as the one by Stedry (1960) who defines a "budget" so that it can be regarded as "one manager's aspirations as to what another manager's aspirations" (e.g., one of his subordinate managers) should be. Stedry also explicitly allows for risk of failure and so his work might form a point of departure which would allow us to adjoin constraints to reflect interacting aspiration level effects and their associated risks of failure with still further behavioral consequences to be considered when the resulting plans are put into action. See Charnes and Stedry (1966) for an example of how this can be done.

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[33] See, e.g., Lewin, Dembo, Festinger and Sears (1944) for a summary of the classical literature. A more up to date coverage may be found in Friar (1986).

[34] Goal programming (and like) formulations may be used as described in Charnes, Cooper, Karwan and Wallace (1979) to resolve such contradictions. See also the exchange between La Valle, Jagannathan and Nau in Jagannathan (1987).

Another very rich set of possibilities is available from the original "satisficing" characterizations provided by H. A. Simon (1957) which can be interpreted via (18)[35] by introducing some additional constraints which are readily included in our models. For instance, we may prescribe "satisfactory levels" of performance and risk in the following form,

$$(19) \qquad Pr[\pi_j x_j \geq \pi_j^*] \geq \alpha_j^*$$

so that this constraint appears as a condition for undertaking the *jth* activity. In addition we may prescribe "overall satisficing conditions" such as

$$(20) \qquad Pr[\sum_{j=1}^{n} \pi_j x_j \geq \pi^*] \geq \alpha^*$$

To be specifically noted is that the condition (20) may introduce an inconsistency in that we may only be able to attain

$$(21) \qquad \max Pr[\sum_{j=1}^{n} \pi_j x_j \geq \pi^*] < \alpha^*$$

in which case the problem has no solution.

This latter case conforms to situations described in Simon (1957) under which either the aspiration level π^* in (20) must be reduced or the risk of its non-attainment $1 - \alpha^*$ must be increased (or both).[36]

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[35] Drenick (1986, p.13) provides a different (but related) characterization of satisficing in terms of set-valued functions.

[36] As noted in the preceding footnote such possibilities may also be handled by returning to a goal programming model format where such inconsistencies are reflected in the magnitude of the goal deviations. This would add the possibility of a change in objectives to the two possibilities mentioned by Simon (1957).

In such cases a behavioral change must be expected of the kind predicted in the prospect theory of Kahneman and Tversky (1979) or else the entire endeavor must be abandoned in favor of a search for new alternatives. Simon seems to have been the only one to allow for the latter possibility explicitly, even though abandonment in favor of a search for new alternatives is a common reaction when confronted with only "unacceptable alternatives" and often plays a central role in the development of corporate strategies. See Ansoff (1965).

Even Simon only adumbrates this possibility, however, and so we do not follow it further here. See Charnes and Stedry (1966) for an example of how such "search" strategies may be included in chance constrained programming models for use in R & D planning. We therefore ignore conditions like (19) and (20) and return to the framework of earlier discussion to show how the E and V terms may be derived as constraints from the P model. We continue to assume that the normal distribution is applicable so that we can draw upon its "reproductive" properties.[37] The use of this 2-parameter distribution also allows us to continue to relate our discussion to the preceding literature on means and variances by reasoning as follows. Given two normal distributions with the same variance, the one with a higher mean will generate values which have a higher probability of equaling or exceeding π^* in (18). See Figure 2 in which $\mu = \mu(z)$ and $z = E\sum_{j=1}^{n}\pi_j x_j$. Similarly given 2 normal distributions with equal means, the one with a smaller variance will generate variates which have a lower probability of falling below π^* when the situation exhibited in Figure 3 obtains – viz., $\pi^* \leq \mu$ so that the aspired level of total profit does not exceed the expected or average total profit.

Insert Figure 2 and 3 around here

Following this line of reasoning we can replace the objective in (18) by the first pair of constraints which are exhibited in the following model. These 2 constraints are adjoined to the risk constraints in the preceding models to obtain:

[37] See the discussion of these properties in chapter 17 of H. Cramer (1946).

$$\max \frac{v}{w}$$

(22) subject to

$$E\sum_{j=1}^{n}\pi_j x_j - v \geq \pi^*$$

$$-E\sum_{j=1}^{n}(\pi_j x_j - \pi^*)^2 + w^2 \geq 0$$

$$\sum_{j=1}^{n} a_{ij} x_j \geq \bar{b}_i + F_i^{-1}(\alpha_i)\sigma_i, \qquad i = 1, 2, \ldots\ldots, m$$

$$v, x_j \geq 0\ , \qquad j = 1, 2, \ldots\ldots, n$$

Here we are using the mean-square error (in the second constraint) rather than variance about the mean since we want the reference to be to π^*, the weighted combination of the aspiration levels π_j^* -- in whatever manner these levels may be prescribed.

Again to be noted is that other risk constraints are the same as in (6) and (8). However, the first two constraints do not appear in (6) or (8). They originate from the functional in the objective of (22) to which they are related by means of the new variables v and w. Evidently the maximizing objective is secured by pushing v up to its highest possible value while "jointly" pushing w down to its lowest possible value to a point where the resulting choices yield the highest value for the ratio of v to w. Thus, as promised, the P-model replaces the separate E and V model optimization with a more general model in which E and V "both" appear as constraints in (22) or as terms to be "jointly" optimized as in the objective of (23) shown below.

Using the theory of fractional programming as is done in Charnes and Cooper (1963), it is possible to simplify the above model, which is a deterministic equivalent of the P model under the assumptions used in its development. We do not follow that route here, however, in order to note that the v/w ratio in (22) implicitly reflects the following more explicit formulation,

$$\max \frac{E\sum_{j=1}^{n}\pi_j x_j}{E\sum_{j=1}^{n}(\pi_j x_j - \pi^*)^2}$$

(23) subject to

$$E\sum_{j=1}^{n}\pi_j x_j \geq \pi^*$$

$$\sum_{j=1}^{n}a_{ij}x_j \geq \bar{b}_i + F_i^{-1}(\alpha_i)\sigma_i$$

$$i = 1, 2, \ldots\ldots, m$$

$$x_j \geq 0\ , \quad j = 1, 2, \ldots\ldots, n$$

If π^* is set equal to the mean, the mean square error in (23) becomes the same as the variance, as defined in the objective for (8).

We now note that the ratio form used in the objective for (23) is not the only possibility for a joint optimization of E and V. To briefly investigate these possibilities we use the following adaptation from Sharpe (1970, pp. 57 ff.):

$$\max \lambda E_p - V_p$$

(24) subject to

$$\sum_{j=1}^{n}x_j = 1$$

$$x_j \geq 0, \qquad j = 1, \ldots\ldots, n\ ,$$

because this formulation also provides ready access to the Sharpe - Lintner CAPM (Capital Asset Pricing Model) which was also discussed in the opening section of this paper.

In (24) E_p and V_p refer to expected returns and variance of returns, respectively, with the subscript p used to show that these returns are calculated as rates rather than in absolute amounts, as was the case in (23). The conditions $\sum_{j=1}^{n}x_j = 1, x_j \geq 0, \ \ j = 1, \ldots\ldots, n$ imply that proportions are being used with at least one $x_j > 0$.[38] Finally, the value of λ is a parameter which is to be prescribed in a way that represents the tradeoff that an investor is willing to make between expected return (as measured by E_p) and risk (as measured by V_p).

Figure 4 is intended to help this discussion by interpreting it as follows. The horizontal and vertical axes are calibrated to values of σ_p and E_p, respectively. The region bounded by the curved lines represents feasible combinations, i.e., values of E_p and V_p which are available from choices that satisfy the constraints in (24). Portfolios which are associated with (E_p, σ_p) pairs at points like c are said to be "inefficient" since other choices are available which satisfy the constraints with better E_p and/or σ_p values. Evidently a point must be on the frontier to be efficient, but being positioned on the frontier does not guarantee efficiency as witness d which can be bettered in both E_p and σ_p by movement to a. In fact a is the point of minimum risk from the available portfolios and is achieved by setting $\lambda = \lambda_0 = 0$ in (24). Conversely, b is the point of maximum E_p which is achieved by setting $\lambda = \lambda_\infty$ which is some dominatingly large value so that the value of V_p is ignored in the optimization. Only points on the frontier between a and b are efficient and these are all secured by varying λ in the range $\lambda_0 \leq \lambda \leq \lambda_\infty$ in (24).

The straight line extending from R_f which is tangent to m is called the capital market line and m represents an optimal portfolio of risky securities. R_f is the riskless rate of interest.[39] At R_f in Figure 4 the investor has all funds in the riskless security and at m the investor has all funds in the optimal portfolio of risky securities. At points in between the investor will have some funds invested in the riskless and some in the risky portfolio and is said to have lent some funds and invested the remainder. With each such choice an E_p, V_p coordinate pair on the line between R_f and m will exhibit the risk-return

[38] Negative x_j values are allowed when borrowing and/or short sales are to be considered. See Sharpe (1970) Ch. V ff.

[39] E.g., in the form of deposits or withdrawals from an insured bank deposit or a suitable evidence of govermnent indebtedness such as a short-term Treasury bill.

values[40] and, under CAPM assumptions, each such (E_p, V_p) choice determines a unique normal distribution which characterizes the probabilistic behavior of all returns in the thus selected portfolio. Finally, if the conditions $x_j \geq 0$ are omitted in (24), points are made available on the line to the right of m and these points will yield E_p, V_p values which are obtainable by borrowing funds at the riskless rate and investing them in the optimal portfolio.

Writing the equation of this line in slope intercept form we have $E_p = R_f + r_e \sigma_p$ Thus, at m,

$$(25) \qquad \begin{aligned} R_m &= R_f + r_e \sigma_m \quad \text{or} \\ r_e &= \frac{R_m - R_f}{\sigma_m} \end{aligned}$$

where R_m is the rate of return on this portfolio and σ_m is its risk or variability measure.

Now consider a point like j in Figure 4 which represents a security with return R_j and σ_j as its variability, or risk, as measured by its standard deviation. Combinations of j and m with $x_j + x_m = 1$ will give

$$(26) \qquad \begin{aligned} E_p &= R_j x_j + (1 - x_j) R_m \\ \sigma_p &= \left[R_j x_j^2 + (1 - x_j)^2 R_m + 2x_j(1 - x_j) cov(R_j, R_m) \right]^{1/2} \end{aligned}$$

with slope at m given by[41]

$$(27) \qquad \frac{\partial E_p}{\partial \sigma_p} = \frac{(R_j - R_m)\sigma_m}{Cov(R_j, R_m) - Var(R_m)},$$

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[40] Here we are using the terminology from market portfolio and capital asset pricing models when referring to E_p and V_p as returns and risks. The satisficing interpretation we have accorded to the P-model of (18) ff. would assert that the objective is to maximize the probability of attaining *both* of Baron Rothschild's objectives -- viz., the objective is to be able to eat and sleep "well enough."

[41] The complete derivation is given on p. 87 of Sharpe (1970).

where $Cov(R_m, R_j)$ is defined as in (2) and $Var(R_m) = \sigma_m^2$.

Equating the expressions in (25) and (27) and simplifying produces

$$(28) \qquad R_j = R_f + \frac{Cov(R_j, R_m)}{Var(R_m)}(R_m - R_f)$$

which is the same as the CAPM equation given in (2) with

$$(29) \qquad \beta_j = \frac{Cov(R_j, R_m)}{Var(R_m)} ,$$

representing "systematic" or "market" risk.

Even when the objective and constraints in (23) are restated to secure conformance with (24) the optimal solutions need not be the same.[42] The point m in Figure 4 is optimal for both, however, so that everything comes together for the P-model, with its satisficing interpretation and the portfolio market strategies and the CAPM from finance. We can also relate these results to the Bowman paradox with which we began. In particular this paradox would be exhibited in Figure 4 by assuming that investments were being made on a line with positive intercept and negative slope and thus would *a fortiori* be inefficient with increasing risk and lower returns for all movements away from the origin.

VII. Uses and Interpretations

There is little question as to the importance that portfolio theory research and its CAPM extensions have had for their effects on actual practices in strategic planning for making interfirm (or intersecurity) comparisons and evaluations in choosing and implementing investment strategies. Evidently our P-model formulation and development has made contact with these approaches which can thus

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[42] See Charnes, Kortanek and Lovegren (1983) for a general development in a saddle value context.

be fitted into our chance constrained programming risk and reward formulations. Notice, for instance, that the risk constraints in our models starting with (6) are available for use in planning and evaluating combinations of different portfolios as well as individual portfolios -- where (as is often the case in investment planning) a single company offers different portfolios that fill particular niches or follow different investment strategies. This is analogous to what was described in earlier our discussion of uses of chance constrained models for guiding and controlling activities such as the marketing and manufacturing components of a strategic plan for companies in fields other than securities market investing.

The above contacts with portfolio theories and practices in finance were derived on the assumption of normally distributed returns. Our P-model remains intact, however, even when these assumptions are dropped and/or when variance is not used as a measure of risk. For a concrete example of such a use, with *ex post* data, we might turn to the "Mutual Fund Scoreboard" published by *Business Week*.[43] In its ratings of some 600 mutual funds (with their strategic objectives explicitly identified), this report by *Business Week* identifies risk with return below the Treasury bill return. As stated on p.85,

> To derive each fund's level of risk, the monthly Treasury bill return is subtracted from the return for each fund for each of the 60 months in the rating period. When a fund has not performed as well as Treasury bills, this monthly result is negative. The sum of these negative numbers is then divided by the number of months in the period. The result is a negative number, and the greater its magnitude, the higher a shareholder's risk of loss.

In a manner consistent with a use of the Treasury bill rate as the π^* value to be used in a P-model objective (or constraint) the *Business Week* report then assigns each mutual fund to a risk class defined by reference to the probability of occurrence of this level of a negative value (or worse) by reference to a standardized normal distribution.

This, of course, is an illustration from finance. However, a similar P-model approach can be used in conjunction with *ex post* data in other contexts provided it is possible to secure some idea of the as-

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[43] See the article "The Best Return for the Least Risk" in the *Business Week*, Feb. 20, 1989, pp. 80 - 114.

piration levels being used. To some extent this may require experimentation, as in the case of Lev (1969), and in other cases auxiliary devices may be needed as in the survey instruments used by Singh (1986). Other uses of our P-models and/or our E and V models can be used in other ways as well -- including full-scale uses for *ex ante* planning where many different dimensions of risk may need to be simultaneously considered.

VIII. Conclusion

Starting with a review of the strategic management literature, we have covered the treatment of risk in the literatures of economics, psychology and organization theory as well. This coverage, although extensive, is far from complete as evidenced by the exclusion of topics like "stochastic dominance" and the only brief references to the decision theory literature.[44] The treatments in the latter literatures generally intermingle the reward and risk structures and hence differ from the separations suggested here -- viz., we are using an approach in which risks are generally assigned to the constraints and rewards are positioned in the functional used to define the objective (or objectives) being pursued. Hence we can say that we have tried to provide a way of approaching the topic of risk in strategic planning that differs from the ones used in decision theory while leaving open the possibilities of using other approaches including approaches like the one used by McCrimmon and Wehrung (1986) in their decision theoretic oriented survey of management decision making under risk.

We have used chance constrained programming as a framework not only to relate different approaches to one another but also to try to clarify the meanings and limitations of some of the ways in which risk has been measured in those literatures. Thus, in particular, we have associated risks with

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[44] Laughhunn, Payne and Crum (1980) has a good treatment of modifications such as those of Fishburn (1977) to include treatments of below-target returns. See also Lee and Rao (1988) for a treatment which relates this to stochastic dominance via the Bawa-Lindenberg (1977) mean-lower partial moment framework.

the probabilities of unfavorable events and shown how these risks can be related to variance as a measure of (lack of) information with respect to mean (or expected value) behavior. This interpretation of variance as a measure of information does not mean that all uses of variance as a measure of risk should be avoided. Variance can perform satisfactorily as a measure of risk in certain contexts. Allowance must also be made for the possibility that inadequate measures may be employed with insight that more than compensates for this inadequac . Bowman's (1980, 1982) studies provide examples which succeeded in awakening interest in the previously under-researched topic of risk and how it should be treated in strategic management.

In this development we have generally allocated risks to the constraints and located the rewards being pursued in E, V and P objectives. Other objectives are also possible, of course, and it may be desirable to intermingle the risks and rewards for certain types of plans and organization structures. A case in point would occur in cases like the ones which were formalized in Ruefli (1968, 1971) where goals are to be determined jointly by top- and down-the-line managers. Even in cases like the latter, however, it is possible to extend our chance constrained programming formulations by using risk adjusted goals that make it possible to identify risks and allow for their separation from rewards in evaluations that might be used en route to arriving at finally developed plans.

Finally our models can readily incorporate multiple risks and provide for situations in which the components of a strategic plan need to be evaluated and coordinated relative to each other as well as to overall company objectives. The idea is to provide an opportunity not only for use in company planning but also to allow for research that can accompany such uses with added contributions on the meaning (and dimensions) of risk that can be perceived and used to guide other research that could prove of value in improving the risk evaluation components in strategic management.

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Figure 1

Fractile Value Representation

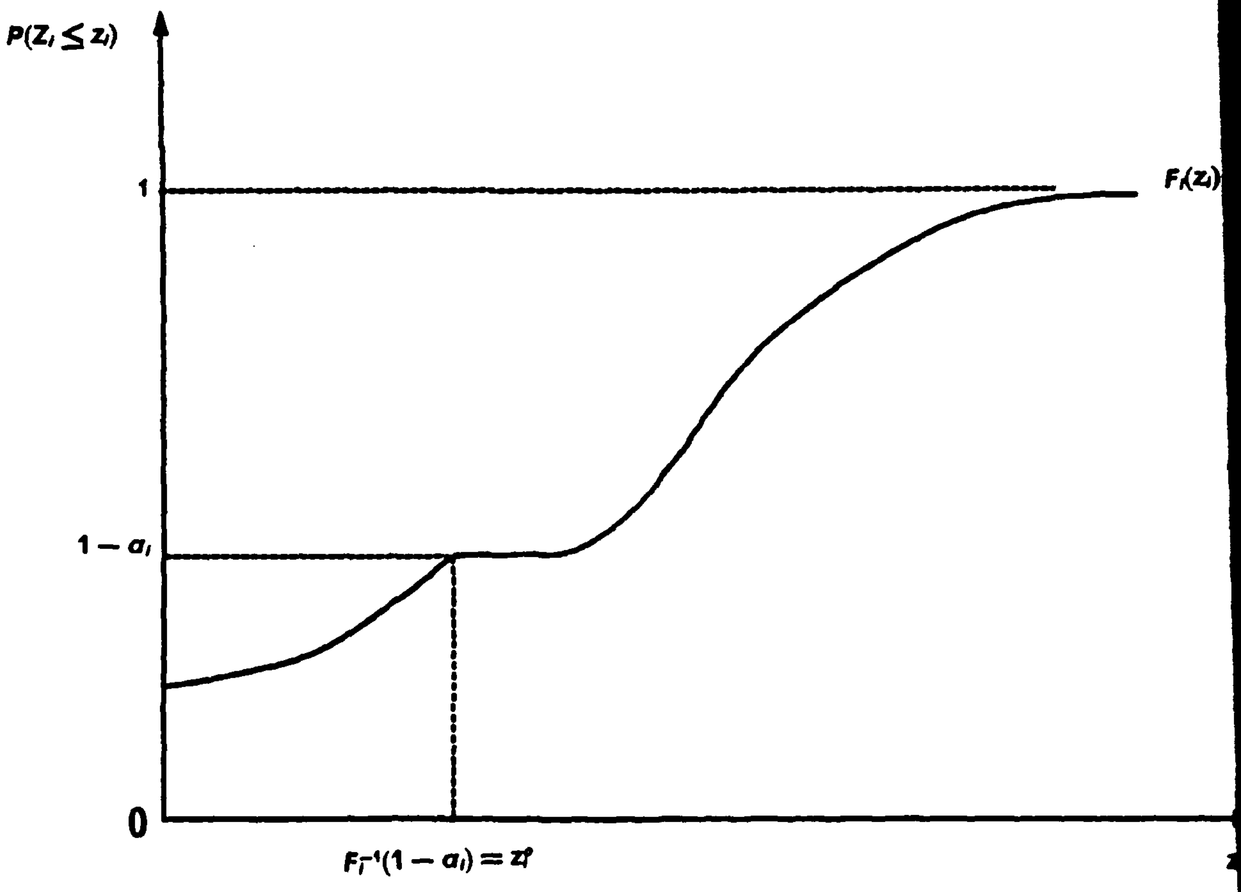

Figure 2

Two Normal Distributions with the Same Variance

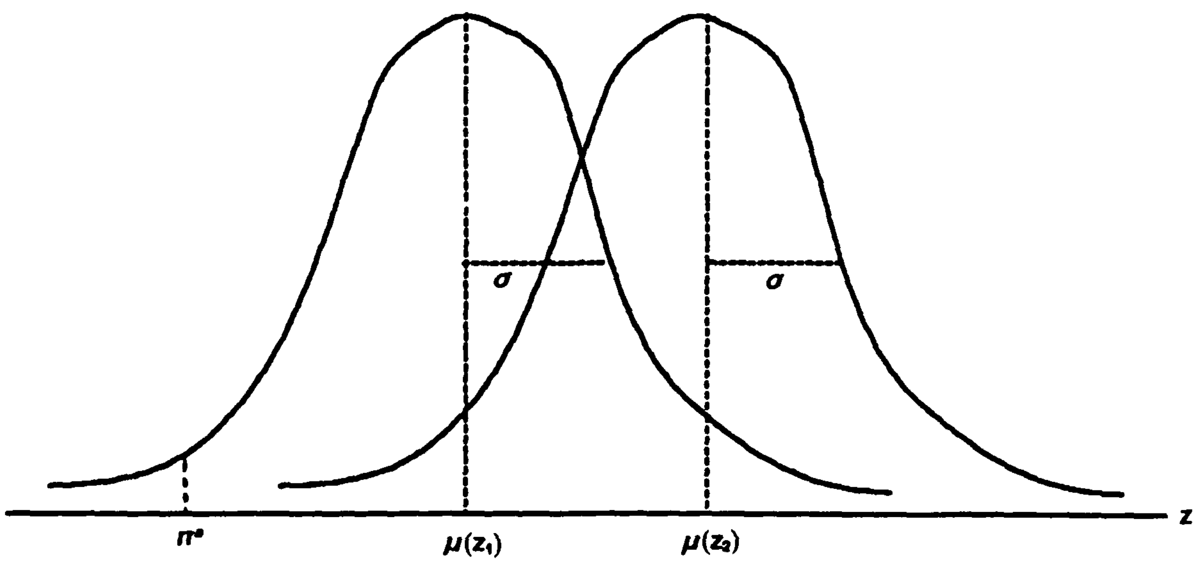

Figure 3

Two Normal Distributions with Equal Means

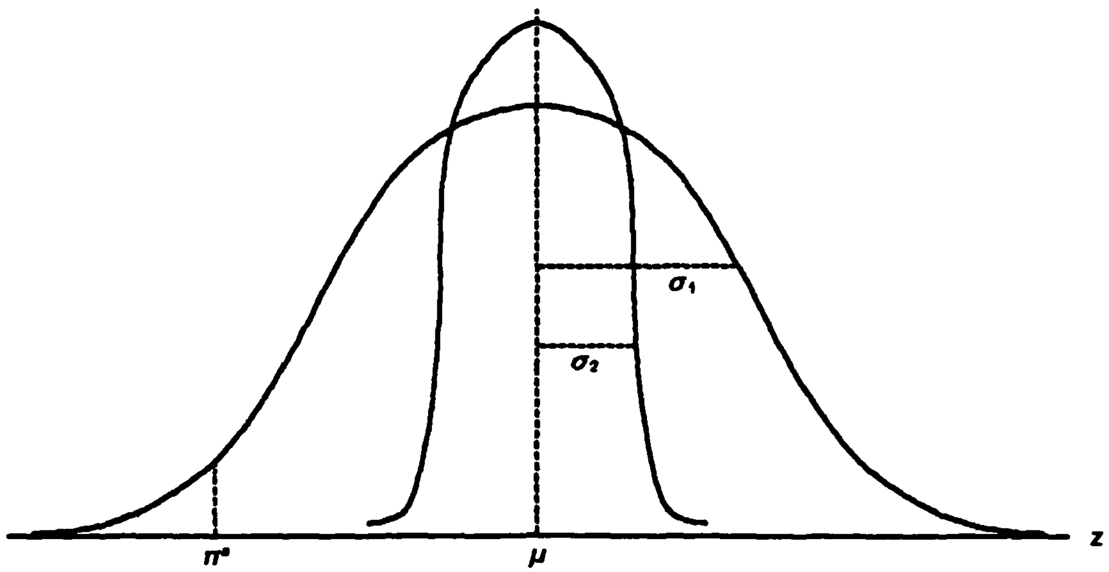

Figure 4

Portfolio Analysis